

I CLAIM:     ~~the remote user data source to a first remote spread spectrum~~

1. In a ~~spread spectrum CDMA~~ digital cellular radio system for communicating between a base station and a mobile terminal over a duplex radio channel, a mobile terminal comprising:

5     a remote user data source for generating a user data signal;

     a first orthogonal code set generator for generating a first orthogonal code and a first remote pilot code;

     a first modulo-two adder, coupled to said remote user data source and to said first orthogonal code set generator, for spread spectrum processing the user data signal with the first orthogonal code to generate a spread signal;

     a first noise-like code generator for generating a first pseudo-noise code;

     a second modulo-two adder, coupled to an output of said first modulo-two adder and to said first noise-like code generator, for processing the spread signal with the first pseudo-noise code to generate a spread spectrum user data signal;

     a remote pilot data source for generating a pilot data signal;

20     a third modulo-two adder, coupled to said first orthogonal code set generator and to said remote pilot data source, for spread spectrum processing the pilot data signal with the first remote pilot code to generate a spread pilot signal;

     a fourth modulo-two adder, coupled to an output of said third modulo-two adder and to said first noise-like code generator, for processing the spread pilot signal with the first



determine a range between the base station and the mobile terminal using round trip delay; and

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a processor, coupled to said code phase adjuster, for generating the processor input and for storing the range between the base station and the mobile terminal.

2. The mobile terminal as set forth in claim 1, said code phase adjuster further for adjusting the phase of the first orthogonal code to have a same phase as the first pseudo-noise code, a length of the first pseudo-noise code being an integer multiple of a length of the first orthogonal code.

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3. The mobile terminal as set forth in claim 1, the code phase adjuster further for shifting, responsive to acquisition, a phase of the first remote pilot code to be synchronous with the spread spectrum user data signal.

4. The mobile terminal as set forth in claim 1 wherein the remote pilot data source generates a pilot data signal that is one of all zeros and all ones.

5. The mobile terminal as set forth in claim 1 wherein said first orthogonal code set generator generates a code of a plurality of codes belonging to a specific set of orthogonal codes.

6. The mobile terminal as set forth in claim 1, further comprising:  
a power splitter for separating the composite spread-spectrum modulated carrier signal into a pilot channel and a data channel;

a second orthogonal code set generator for generating, responsive to a command from the base station, a locally generated pilot code;

a second noise-like code generator for generating a second pseudo-noise code;

a mode control and acquisition device, coupled between said second orthogonal code set generator and said second noise-like code generator, for receiving timing information from the base station and for generating a clock for said second orthogonal signal code set generator and said second noise-like code generator, and a synchronization signal;

a clock pulse generator, coupled to said mode control and acquisition device and to said first orthogonal code set generator and said first noise-like code generator for providing a synchronous clock signal;

a fifth modulo-two adder, coupled to said second orthogonal code set generator and to said second noise-like code generator, for combining the locally generated pilot code and the second pseudo-noise code to form a first local spread-spectrum-pilot-reference signal;

a sixth modulo-two adder, coupled to said second orthogonal code set generator and to said second noise-like code

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generator, for combining a specified orthogonal code and the  
second pseudo-noise code to form a first local spread spectrum  
information reference signal;

a first delay device, coupled to said fifth modulo-two  
adder, for delaying, responsive to the processor, the first local  
spread-spectrum-pilot-reference signal to generate an on-time, an  
early, and a late version of the first local spread-spectrum-  
pilot-reference signal;

a first, a second, and a third multiplier/correlator,  
each coupled to said power splitter and to said first delay  
device, for multiplying the composite-spread-spectrum-modulated-  
carrier signal with the on-time, the early, and the late versions  
of the first local spread-spectrum-pilot-reference signal to  
correlate out an on-time, an early, and a late version of the  
common-shared-spread-spectrum-pilot signal, respectively;

a second delay device, coupled to said sixth modulo-two  
adder and to said processor, for providing an information  
reference signal synchronized with the on-time version of the  
first local spread-spectrum-pilot-reference signal;

a fourth multiplier/correlator, coupled to said second  
delay device and to said power splitter, for multiplying the  
composite spread-spectrum modulated carrier signal with the first  
local spread spectrum information reference signal to correlate  
out the specific spread spectrum user information channel;

a delay lock loop, coupled to said second and third  
multiplier/correlators, for tracking a phase of the incoming  
common-shared-spread-spectrum-pilot signal and for outputting,

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responsive to a correlation peak, a clock signal and an error correction  
acquisition signal to the mode control and acquisition device;  
and

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a phase lock loop oscillator, coupled to said first  
multiplier/correlator, for centering on the correlation peak and  
for providing a coherent carrier reference to a local data  
detector and to said delay lock loop.

7. The mobile terminal as set forth in claim 1, wherein  
said common-shared-spread-spectrum-pilot signal contains an  
orthogonal code element.

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8. The mobile terminal as set forth in claim 1, wherein  
said first remote pilot code contains an orthogonal code element.

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9. The mobile terminal as set forth in claims 6, 7 or 8,  
wherein said base station measures the code phase difference  
between the common-shared-spread-spectrum-pilot signal and the  
first remote pilot code to determine a range between the base  
station and the mobile terminal.

10. In a spread spectrum CDMA digital cellular radio system  
for communicating between a base station and a plurality of  
mobile terminals over a duplex radio channel, a base station  
comprising:

a base user data source for generating a base user data  
signal;

a first orthogonal code set generator for generating a first orthogonal code and a first base pilot code;

10 a first modulo-two adder, coupled to said base user data source and to said first orthogonal code set generator, for spread spectrum processing the base user data signal with the first orthogonal code to generate a spread signal;

a first noise-like code generator for generating a first pseudo-noise code;

15 a second modulo-two adder, coupled to an output of said first modulo-two adder and to said first noise-like code generator, for processing the spread signal with the first pseudo-noise code to generate a spread spectrum user data signal;

20 a system data source for generating system data to be transmitted to the plurality of mobile terminals;

system data spreading means for spread spectrum processing the system data;

a base pilot data source for generating a base pilot data signal;

25 pilot data signal spreading means for spread spectrum processing the base pilot data signal with the first base pilot code as a common-shared-spread-spectrum-pilot signal;

30 a signal combiner, coupled to said pilot data signal spreading means, said system data spreading means, and said second modulo-two adder, for combining the common-shared-spread-spectrum-pilot signal, the spread spectrum processed system data, and the spread spectrum user data signal as a combined spread spectrum data signal;

35 a modulator, coupled to said signal combiner, for  
modulating the combined spread spectrum data signal onto a  
carrier as a combined spread spectrum modulated data signal;

40 antenna means for transmitting the combined spread-  
spectrum modulated data signal and for receiving a plurality of  
composite spread-spectrum modulated carrier signals transmitted  
from a plurality of mobile terminals, respectively, each  
composite spread-spectrum modulated carrier signal having a  
received-remote-spread-spectrum-pilot signal and an information  
channel for each mobile terminal;

45 pilot-reference-signal generating means for generating  
a pilot-reference signal;

a clock pulse generator, coupled to said first  
orthogonal code set generator and to said first noise-like code  
generator, for maintaining system-wide time;

50 range delay means, coupled to an output of said pilot  
data signal spreading means and said pilot-reference-signal  
generating means, for calculating a phase difference between the  
pilot-reference signal and the common-shared-spread-spectrum-  
pilot signal as a first value; and

55 a processor for storing the first value and for  
providing, using the first value, a processor output representing  
round trip delay for transmission to the mobile terminal.

11. The base station as set forth in claim 10, said pilot data signal spreading means comprising:

a third modulo-two adder, coupled to said first orthogonal code set generator and to said base pilot data source, for spread spectrum processing the pilot data signal with the first base pilot code to generate a spread pilot signal; and

a fourth modulo-two adder, coupled to an output of said third modulo-two adder and to said first noise-like code generator, for processing the spread pilot signal with the first pseudo-noise code to generate the common-shared-spread-spectrum-pilot signal.

12. The base station as set forth in claim 11, said system data spreading means comprising:

said first orthogonal code set generator for generating a second orthogonal code;

a fifth modulo-two adder, coupled to said first orthogonal code set generator and to said system data source, for spread spectrum processing the system data with the second orthogonal code to generate a spread-spectrum-data signal; and

a sixth modulo-two adder, coupled to an output of said fifth modulo-two adder and to said first noise-like code generator, for processing the spread-spectrum-data signal with the first pseudo-noise code to generate the spread-spectrum-system-data signal.

13. The base station as set forth in claim 12, further comprising:

a power splitter for separating the composite spread-spectrum modulated carrier signal into a pilot channel and a data channel;

a second orthogonal code set generator for generating a third orthogonal code;

a second noise-like code generator for generating a second pseudo-noise code;

a mode control and acquisition device, coupled between said second orthogonal code set generator and said second noise-like code generator, for providing clock and control signals;

a seventh modulo-two adder, coupled to said second orthogonal code set generator and to said second noise-like code generator, for combining an assigned pilot orthogonal code and the second pseudo-noise code to form a first spread-spectrum-pilot-reference signal;

an eighth modulo-two adder, coupled to said second orthogonal code set generator and to said second noise-like code generator, for combining an assigned data orthogonal code and the second pseudo-noise code to form a first spread spectrum data reference signal;

a first delay device, coupled to said seventh modulo-two adder, for delaying, responsive to the processor, the first spread-spectrum-pilot-reference signal to generate an on-time, an early, and a late version of the first spread-spectrum-pilot-reference signal;



14. The base station as set forth in claim 10 wherein said base station measures a code phase difference between the common-shared-spread-spectrum-pilot signal and the received-remote-spread-spectrum-pilot signal to determine a range between the base station and each mobile terminal.

15. The base station as set forth in claim 14, said mobile terminal adjusting, responsive to the round trip delay, a code phase of the information channel of each composite-spread-spectrum-modulated-carrier signal to coincide with a specific time mark as the composite-spread-spectrum-modulated-carrier signal arrives at the base station.

16. The base station as set forth in claim 15, with the information channel of each composite-spread-spectrum-modulated-carrier signal of each of the plurality of mobile terminals phase adjusted to coincide with said specific time mark at the base station.

17. The base station as set forth in claim 16, wherein said base station sets the specific time mark at an absolute time value to satisfy cell orthogonality criteria.

18. A spread-spectrum CDMA digital cellular radio system for communicating between a base station and a mobile terminal over a duplex radio channel and for range locating said mobile terminal, said spread-spectrum CDMA digital cellular radio system comprising:

a plurality of mobile terminals, each of said plurality of mobile terminals including,

remote-spread-spectrum-processing means for processing remote-message data using a pseudo-noise code;

remote-pilot means for generating a remote-pilot signal;

combining means, coupled to said remote spread-spectrum-processing means and to said remote-pilot means, for combining the remote-pilot signal with the spread-spectrum-processed-remote-message data to generate a remote composite signal;

remote-transmitting means for transmitting the remote composite signal to the base station on a reverse channel of the duplex radio channel;

said base station including,

receiving means for receiving the remote composite signal;

first-base-pilot means for generating a base pilot signal;

second-base-pilot means for generating a base-pilot-reference-signal;

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first delay means for generating an on-time, an early and a late version of the base-pilot-reference-signal;

second delay for generating an information reference signal;

correlator means for multiplying the remote composite signal with the on-time, the early, and the late versions of the base-pilot-reference signal to correlate out an on-time, an early, and a late version of the remote pilot signal, respectively, said correlator means also for multiplying the remote composite signal with the information reference signal to correlate out the remote-user-information channel;

tracking means for tracking a phase of the remote-pilot signal and for outputting, responsive to a peak in the remote-pilot signal, an acquisition signal signifying synchronization of the remote-pilot signal and the base-pilot-reference-signal;

range delay means, responsive to the acquisition signal, for calculating a phase difference between the base pilot signal and the base-pilot-reference-signal to determine a range between the mobile station and the base station; and

base-transmitting means for transmitting the range from the base station to the mobile terminal over a forward channel of the duplex radio channel;

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each of said plurality of mobile terminals further  
including,

55 code phase adjustment means, responsive to the  
range, for adjusting a phase of the pseudo-noise code to  
determine an arrival time of the spread-spectrum-processed-  
remote-message data at the base station.

19. The spread-spectrum CDMA digital cellular radio system  
as set forth in claim 18 further comprising:

base-spreading means for spread spectrum processing  
base-message data, said base-spreading means including means for  
processing base-message data for a particular mobile terminal  
with a selected chip code.

20. The spread-spectrum CDMA digital cellular radio system  
as set forth in claim 18 with said remote-pilot means slaved to  
the base-pilot signal.

21. The spread spectrum CDMA digital cellular radio system  
as set forth in claim 18, said remote spread spectrum processing  
means adjusting, responsive to said base station, the pseudo-  
noise code in increments of a code chip;

5 a base station processor comparing signal strength  
levels of the spread-spectrum-processed-remote-message data as  
the mobile terminal adjusts the pseudo-noise code;

said base station, responsive to a code chip increment  
that maximizes performance, calibrating a relationship between

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the remote-pilot signal and the spread-spectrum-processed-remote-message data with the code chip increment on each of the above arrival

22. The spread spectrum CDMA cellular radio communications system as set forth in claim 18, further comprising:

base-spreading means for spread spectrum processing base-message data;

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base-combining means for combining the spread spectrum processed base-message data and the base pilot signal as a composite base signal, the composite base signal including a common-shared-spread-spectrum-pilot signal and at least one specific spread spectrum user information channel for each mobile terminal, a spreading code of each of said common-shared-spread-spectrum-pilot signal and said specific spread spectrum user information channel containing an orthogonal code element;

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said remote-pilot signal slaved to said common-shared-spread-spectrum-pilot signal as a reference for phase and timing of the remote-pilot signal;

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said remote composite signal including at least one remote spread spectrum user information channel, each of the remote-pilot signal and a spreading code of said remote spread spectrum user information channel containing an orthogonal code element;

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said remote spread spectrum user information channel synchronized to said remote-pilot signal;

said remote spread spectrum user information spreading code further shifted in phase, responsive to range information

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sent from said base station, to be orthogonal with other remote spread spectrum user information spreading codes arriving at said base station.

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23. The spread spectrum CDMA cellular radio communications system as set forth in claim 22 wherein said base station measures a code phase difference between said common-shared-spread-spectrum-pilot signal and said remote-pilot signal to determine range between said base station and said mobile terminal.

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24. The spread spectrum CDMA cellular radio communications system as set forth in claim 23, wherein said mobile terminal, responsive to receiving range information from said base station, adjusts the code phase of said remote spread spectrum user information channel spreading code to coincide with a specific time mark at the base station.

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25. The spread spectrum CDMA cellular radio communications system as set forth in claim 24, wherein said mobile terminal, responsive to receiving an error signal from said base station, adjusts an orthogonal pseudo-noise code phase to compensate for changes in range as the mobile terminal moves within a cell.

26. The spread spectrum CDMA cellular radio communications system as set forth in claim 25, further comprising,

base station delay lock loop means for generating the error signal and for tracking the remote-pilot signal.

27. The spread spectrum CDMA cellular radio communications system as set forth in claim 22, with spreading codes of said remote-pilot signal and said spread-spectrum-processed-remote-message data adjusted in phase with each other to account for orthogonality correction and added together before transmission.

28. The spread spectrum CDMA cellular radio communications system as set forth in claim 26, with said base station delay lock loop means for adjusting a phase of both said remote-pilot signal and said spread-spectrum-processed-remote-message data.

29. A spread-spectrum CDMA cellular radio communications method for communicating remote-message data from a mobile terminal to a base station over a duplex radio channel, and for using a pilot on a return link to achieve orthogonality at a base station antenna, said spread-spectrum CDMA cellular radio communications method comprising the steps of:

spread-spectrum processing the remote message data using a pseudo-noise code;

generating a remote-pilot signal;

combining the remote-pilot signal with the spread-spectrum-processed-remote-message data, to generate a remote-CDMA

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outputting, responsive to a peak in the remote-pilot  
40 signal, an acquisition signal, the acquisition signal signifying  
synchronization of the remote-pilot signal and the base-pilot-  
reference signal;

measuring, responsive to the acquisition signal, a code  
phase difference between the base pilot signal and the base-  
45 pilot-reference signal to determine a range between the mobile  
terminal and the base station;

transmitting the range to the mobile terminal; and  
adjusting a phase at the mobile terminal, responsive to  
the range, of the pseudo-noise code to adjust an arrival time of  
50 the data signal and to achieve orthogonality at the base station.

30. The method as set forth in claim 29, further comprising  
the step of:

phase shifting, responsive to the acquisition signal,  
the remote-pilot signal to be synchronous with the data signal.

55 31. The method as set forth in claim 29, the remote-pilot  
signal slaved to the base-pilot signal.

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